The Ames-Rosenberg Hypothesis Revisited*

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A recent study by Paul Uselding employs econometric techniques to study technical progress at the Springfield Armory during the 1820–1850 period.[1] One portion of Uselding's interesting paper is concerned with the "Ames-Rosenberg hypothesis" which argues, in the context of nineteenth century English gunmaking, that, "Analysis... in terms of a two-factor, capital and labour model,... is fundamentally inadequate because such a model is incapable of calling attention to the importance of the price of 'land' [defined as material inputs], which may have been of major importance in the nineteenth century."[2] If this contention is generally valid, its methodological importance for economic analysis of historical production processes is substantial. Therefore, it is desirable to empirically test the validity of the Ames-Rosenberg contention. In this respect, it is encouraging to observe Uselding's testing of one of the specific implications of Ames-Rosenberg, namely, that if a "material" variable is included in the analysis, it will exhibit a positive output elasticity.[3] Although Uselding's empirical results appear to support the Ames-Rosenberg hypothesis, he rightly qualifies his conclusions:

> ... the inclusion of a material variable... causes the output elasticity of labor to become insignificant, indicating high intercorrelation between these variables. While this finding is only suggestive of the correctness of the Ames-Rosenberg hypothesis, it also indicates that additional research and new data series on this problem are needed.[4]

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[1]Paul J. Uselding, "Technical Progress at the Springfield Armory," *Explorations in Economic History*, 9 (Spring, 1972).

[2]Edward Ames and Nathan Rosenberg, "The Enfield Arsenal in Theory and History," *The Economic Journal*, 78, No. 312 (December, 1968), p. 831.

[3]Uselding, pp. 293–95, 299–300.

[4]*Ibid.*, p. 306.

In the spirit of this remark, our note has as its purpose the inspection of the Ames-Rosenberg hypothesis for early American manufacturing. The data base used is the 1820 Census for Manufactures. This seems to be a virtually untapped source of information on a period termed by Paul David "the statistical dark age."[5] Before employing these data, from which we can generate a tentative production function for 1820 iron products, we suggest that Uselding's formulation of a production function is inappropriate for testing the Ames-Rosenberg hypothesis. Using a different specification, our findings, however, also tend to confirm the hypothesis in question; i.e., the hypothesis is not inconsistent with an appropriately specified test.

I

Quantitative studies of manufacturing before 1840 have frequently relied on records of individual firms, and the Uselding study is a fine example of this approach. However, the 1820 Census for Manufactures, which contains statistics for hundreds of firms, has been almost ignored by economic historians because of the unreliability of the data. Although these criticisms are clearly not without merit, it is possible to use this information for the purpose of specifying production functions, especially after clearly "bad firm observations" have been deleted from the sample.[6]

[5]Paul David, "New Light on a Statistical Dark Age: U.S. Real Product Growth before 1840," *American Economic Review,* 57 (May, 1967).

[6]Parker and Whartenby state that "the 1820 Census for Manufactures was ... notoriously deficient and inaccurate." William N. Parker and Franklee Whartenby, "The Growth of Output before 1840," *Trends in the American Economy in the Nineteenth Century,* Studies in Income and Wealth, NBER, Vol. 24 (Princeton: Princeton University Press, 1960), p. 199. Carroll D. Wright described the census: "The report on manufactures presents the results concerning manufacturing establishments so far as returned in each district and territory, by counties, but the results are not summarized in each district, nor does the report contain any aggregate statement for the entire country—an omission due, doubtless, to the incompleteness of the returns, arising partly from the insufficient compensation allowed for the collection of the returns and partly from the neglect or refusal of manufacturers to supply the necessary information." Carroll D. Wright, *The History and Growth of the United States Census* (56th Cong., 1st Sess., S. Doc. 194, 1900), p. 27. A major deficiency of the census is the incomplete tabulation and the lack of summary tables. The omissions mean that the published report constitutes a sample of manufacturing establishments of an unknown bias. Observations were excluded from the sample where data were missing or where the stated values of one or more statistic de-

One of the advantages of the Census is the degree of detail reported. For each firm the following information is given: the value of output; the value of raw materials; the number of men, women, and children employees; the value of capital invested; and the total annual wage payments. Clearly, this is sufficient for our purposes and, although we share the concern of economic historians about the reliability of studies based on the individual firm observations for 1820, the alternative of leaving the data unanalyzed seems to be less desirable than proceeding.

II

In their Enfield Arsenal article, Ames and Rosenberg state:

> Our conclusion is that two-input (labour and capital) models are inadequate in discussing nineteenth century gunmaking. Three input theories are the staple fare of Anglo-American economics, and it is natural to consider one application of such theories. . . . if 'land' is recognised as an input some of the difficulties about explaining international differences in gunmaking practices might be dealt with.[7]

Uselding formulates this hypothesis more explicitly and tests specifically whether "The presence of a third or 'material' variable in the production function will display significantly non-negative output elasticity."[8] Uselding errs, however, in choosing value added instead of gross output as the dependent variable. His definition of value added is the standard one of the dollar value of annual physical output minus the dollar value of raw materials consumed each year. It is labor and capital inputs which add value to raw materials purchased by the firm. The use of value added is logical when capital and labor are included without raw materials as an independent variable. However, it does not seem appropriate to include raw materials as an independent explanator of value added.

III

To test the Ames-Rosenberg hypothesis, we have estimated a log-linear production function employing the value of gross output

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viated widely from the arithmetic means prevailing for the industry as a whole. For example, the mean wage for all firms producing iron products was $183 per year. Firms reporting average wages of less than $60 (about one-third the mean) or more than $450 (about 2.5 times the mean) were excluded from the sample since the probability of a reporting error presumably was greater for those observations.

[7]Ames and Rosenberg, pp. 830–831.

[8]Uselding, p. 294.

(Q) as the dependent variable, and the value of capital (K), the number of employees (L), and the value of raw materials (M) as independent variables, for 101 firms that produced primarily or exclusively products made from iron in 1820. The results are

$$\text{(1)}\quad \underset{}{\text{Log } Q} = \underset{}{1.26} + \underset{(.04)}{0.19 \text{ Log } K} + \underset{(.04)}{0.33 \text{ Log } L} + \underset{(.03)}{0.45 \text{ Log } M}$$

$$R^2 = .96 \qquad F[3,97] = 715,$$

with standard errors in parentheses.[9] These provide impressive confirmation of the hypothesis in question. For Uselding's formulation, with value added as the dependent variable, we obtain

$$\text{(2)}\quad \underset{}{\text{Log } V} = \underset{}{1.67} + \underset{(.06)}{0.26 \text{ Log } K} + \underset{(.06)}{0.62 \text{ Log } L} + \underset{(.05)}{0.09 \text{ Log } M}$$

$$R^2 = .91 \qquad F[3,97] = 323.$$

The coefficients for capital and labor increase and that of materials decreases drastically, thereby weakening the case for the Ames-Rosenberg thesis.[10]

IV

To conclude, we have argued that the correct form of a production function which includes materials as an input is one which specifies gross output and not value added as the dependent variable. Using this form of a production function, we have presented empirical results for the iron industry in 1820 that lend stronger support to the Ames-Rosenberg hypothesis than that provided by Uselding's Springfield Armory data or, for that matter, stronger than those which would be obtained by applying the Uselding test to our data. Consequently, our findings serve to reinforce the Ames-Rosenberg injunction to historical researchers to look to models of the production process that avoid what they call the "high cost of compression in moving from a three-factor to a two-factor model."[11]

[9]If one uses a two-variable function (capital and labor) with value added as the dependent variable, the empirical results are

$$\text{Log } V = \underset{}{1.77} + \underset{(.05)}{0.31 \text{ Log } K} + \underset{(.06)}{0.64 \text{ Log } L}, \quad R^2 = .95$$

[10]Using a two-tailed test the material regression coefficient is not significantly different from zero at the 5% level.

[11]Ames and Rosenberg, p. 831.